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Design of a Multimodal Attendance System Using RFID, Face Recognition, Fingerprint Biometric, and GSM Notification

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Abstract: Accurate and tamper-proof attendance monitoring is a challenge in educational, corporate and administrative settings. Existing systems that are solely dependent on manual entry, RFID card or biometric authentication with single-mode are often vulnerable to manipulation, impersonation and inconsistency of data. This study presents the design and implementation of a multimodal attendance system that integrates radio frequency identification (RFID), face recognition, fingerprint biometric and GSM-based SMS notifications to improve reliability, safety and accountability. The proposed system uses an ESP32 microcontroller to coordinate multiple hardware modules, including an RC522 RFID reader, an AS608 fingerprint sensor, an ESP32-CAM for facial recognition, and a SIM800L GSM module for mobile communication. Upon RFID approval, the system performs sequential fingerprints and face recognition, and ensures identity confirmation through at least two biometric modalities. Successful verification triggers real-time logging, timestamp and an SMS notification to a designated recipient. Experimental validation was performed using a test population, and the results show improved accuracy, low false acceptance/rejection rate and real-time responses. The system supports local data storage and provides scalability for integration with cloud -based platforms. This research contributes to the development of secure, efficient and user-centric attendance management systems through the deployment of multimodal biometric technologies.

Keywords: *Attendance System, Biometric Authentication, Face Recognition, Fingerprint Sensor, RFID.*

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I. INTRODUCTION

Attendance monitoring is a fundamental aspect of operational efficiency in educational institutions, corporate ins and secure facilities. Conventional attendance methods such as manual registers or single RFID card systems are increasingly inadequate due to weaknesses such as impersonation, Buddy Punching and lack of real-time data synchronization. Institutions or organizations require more secure, strong and automated solutions, multimodal biometric systems provide a valid option using multiple verification methods.

Multimodal authentication systems combine two or more biometric or identification authentication methods to ascertain a person's identity. Using RFID cards, facial features and fingerprint data in a single framework, these systems can reduce the speed of false acceptance, prevent impersonation and improve the accuracy of access control. This article describes the development of a real-time multimodal attendance system using an ESP32 microcontroller to coordinate RFID, facial validation and fingerprint biometric, in which GSM-based SMS notification provide real-time response.

II. LITERATURE REVIEW

Several studies have explored different approaches to improve attendance systems using automation and biometrics. RFID-based systems are one of the most adopted because of their ease of use and low implementation costs. However, RFID systems alone have been criticized for their susceptibility to abuse, especially through card sharing or cloning (Olanipekun & Boyinbode, 2015).

Recognition of fingerprints provides safer authentication, but suffers from performance degradation due to dirty or injured fingers, sensor wear or spoofing attack (Riaz et al., 2024; Henniger et al., 2021).

Face recognition has proven to be a contactless and increasingly accurate approach due to advances in deep learning and computer vision algorithms. Nevertheless, factors such as lighting conditions, facial expressions and

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occlusions can limit its efficiency (Palanichamy, 2024; Kavi & Deepa, 2024).

Multimodal biometric systems try to overcome these limitations by combining different authentication factors. Research by Singh et al. indicates that the integration of fingerprints and facial recognition reduces error rate and improves reliability.

Sharma et al. (2024) demonstrated the effectiveness of combining RFID with fingerprint recognition to improve both user compliance and the system's robustness. However, existing solutions often lack communication capabilitiess in real time that can notify supervisors, parents or managers. The integration of GSM-based SMS notifications provides a layer of immediacy and accountability that many current systems lack.

➢ *System Architecture*

The architecture of the proposed system is designed around four primary modules: the RC522 RFID reader, AS608 fingerprint sensor, ESP32-CAM for facial recognition, and the SIM800L GSM module for real-time SMS alerts. These modules are interfaced with the ESP32 microcontroller, which serves as the central control unit.

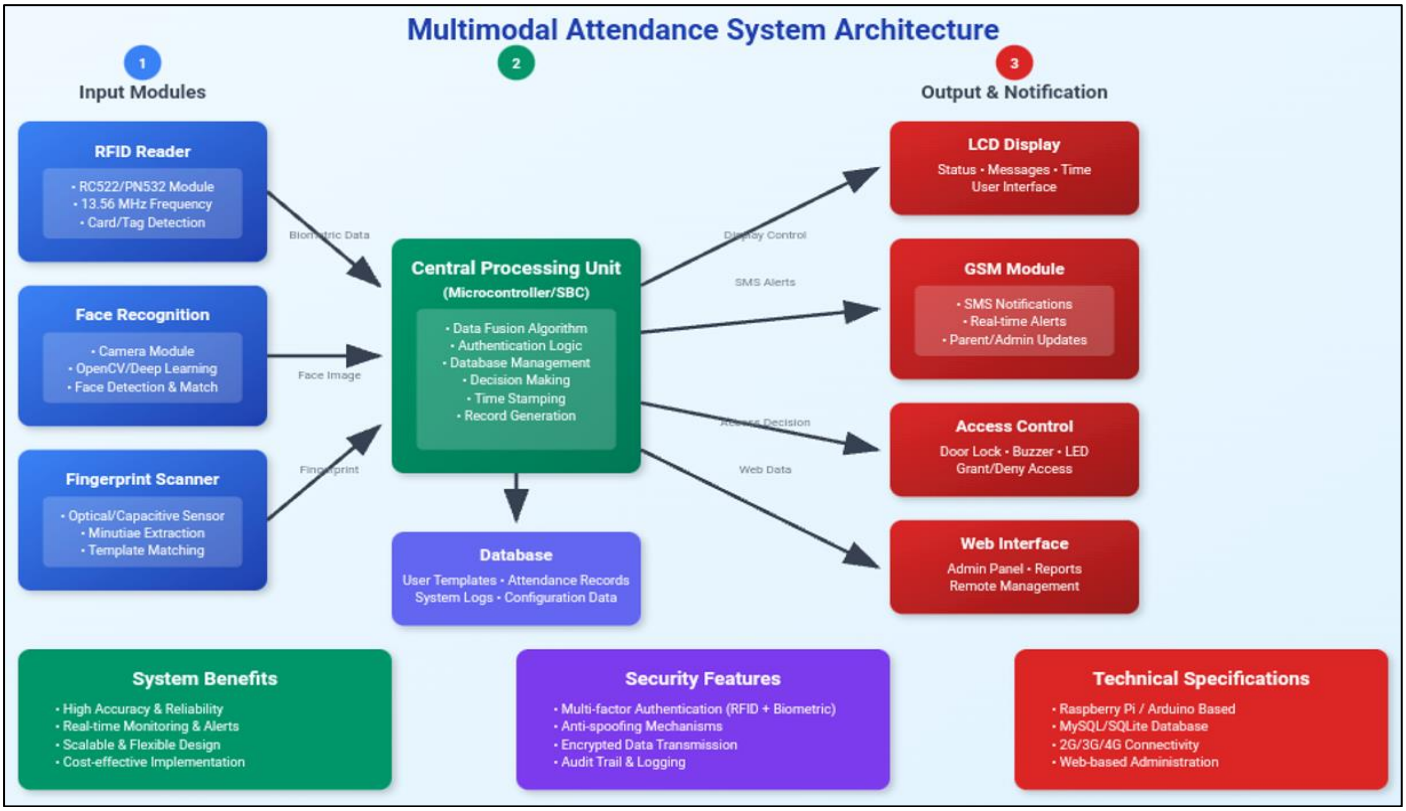

Fig 1 Multimodal Attendance System Architecture

➢ *Hardware Components*

- *ESP32:*

Serves as the main microcontroller, equipped with WiFi and Bluetooth, GPIO pins, and sufficient processing power to coordinate all modules.

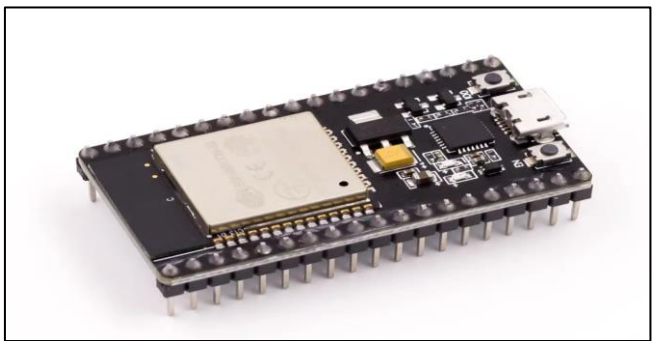
Fig 2 ESP32

- *RC522 RFID Reader:*

A 13.56 MHz reader capable of detecting MIFARE cards, used for initial identification.

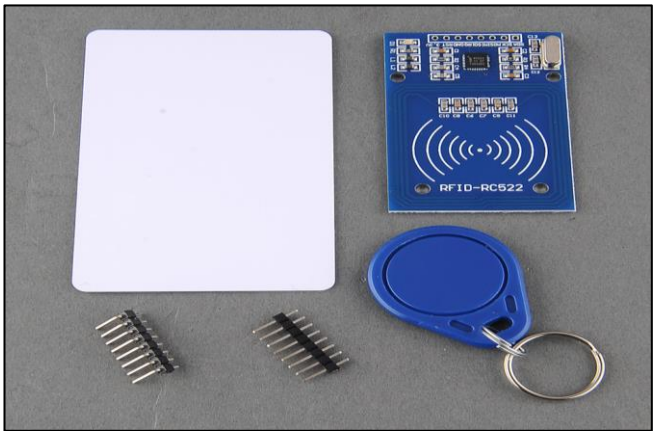

Fig 3 RC522 RFID Reader

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- *AS608 Fingerprint Module:*
  Optical fingerprint sensor with built-in processing for enrollment and matching.

Fig 4 AS608 Fingerprint Module

- *ESP32-CAM:*
  Microcontroller with an integrated OV2640 camera for face detection and recognition.

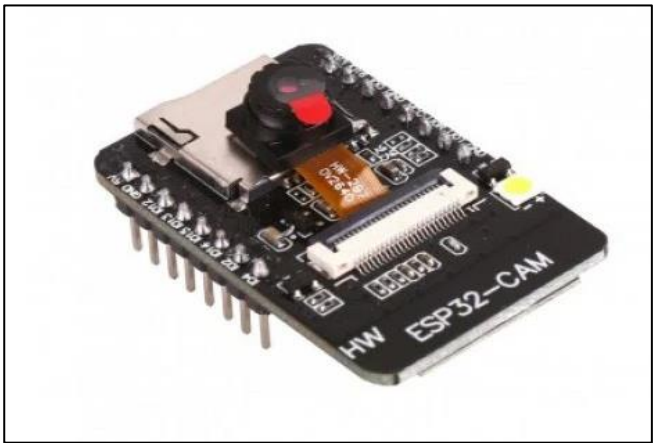

Fig 5 ESP32-CAM

- *SIM800L GSM Module:*
  Enables SMS communication to predefined phone numbers.

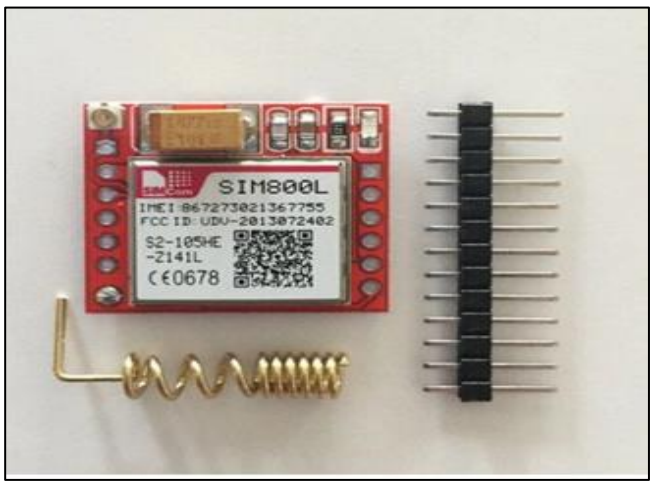

Fig 6 SIM800L GSM Module

- *OLED Display:*
  Displays system messages such as prompts and success/failure indicators.

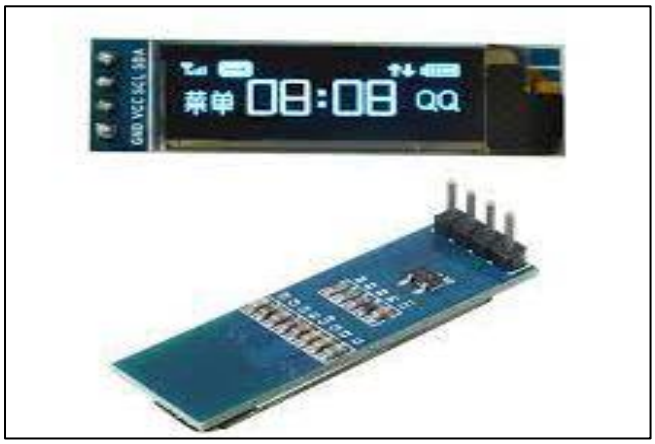

Fig 7 OLED Display

- *RTC DS3231 Module:*
  Maintains accurate time even during power loss.

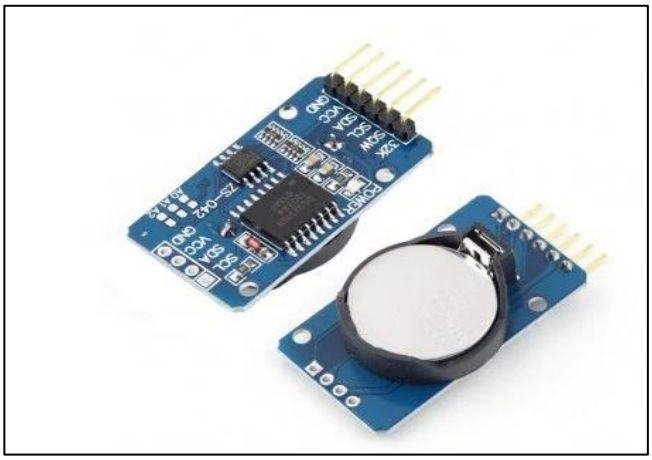

Fig 8 RTC DS3231 Module

- *MicroSD Card Module:*
  Stores attendance logs for offline review.

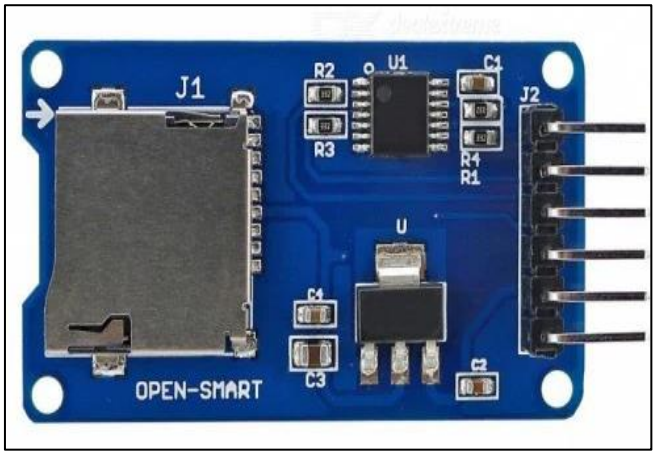

Fig 9 MicroSD Card Module

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➢ *Software Stack*

- *Arduino IDE:*
  Used for writing and uploading code to the ESP32.

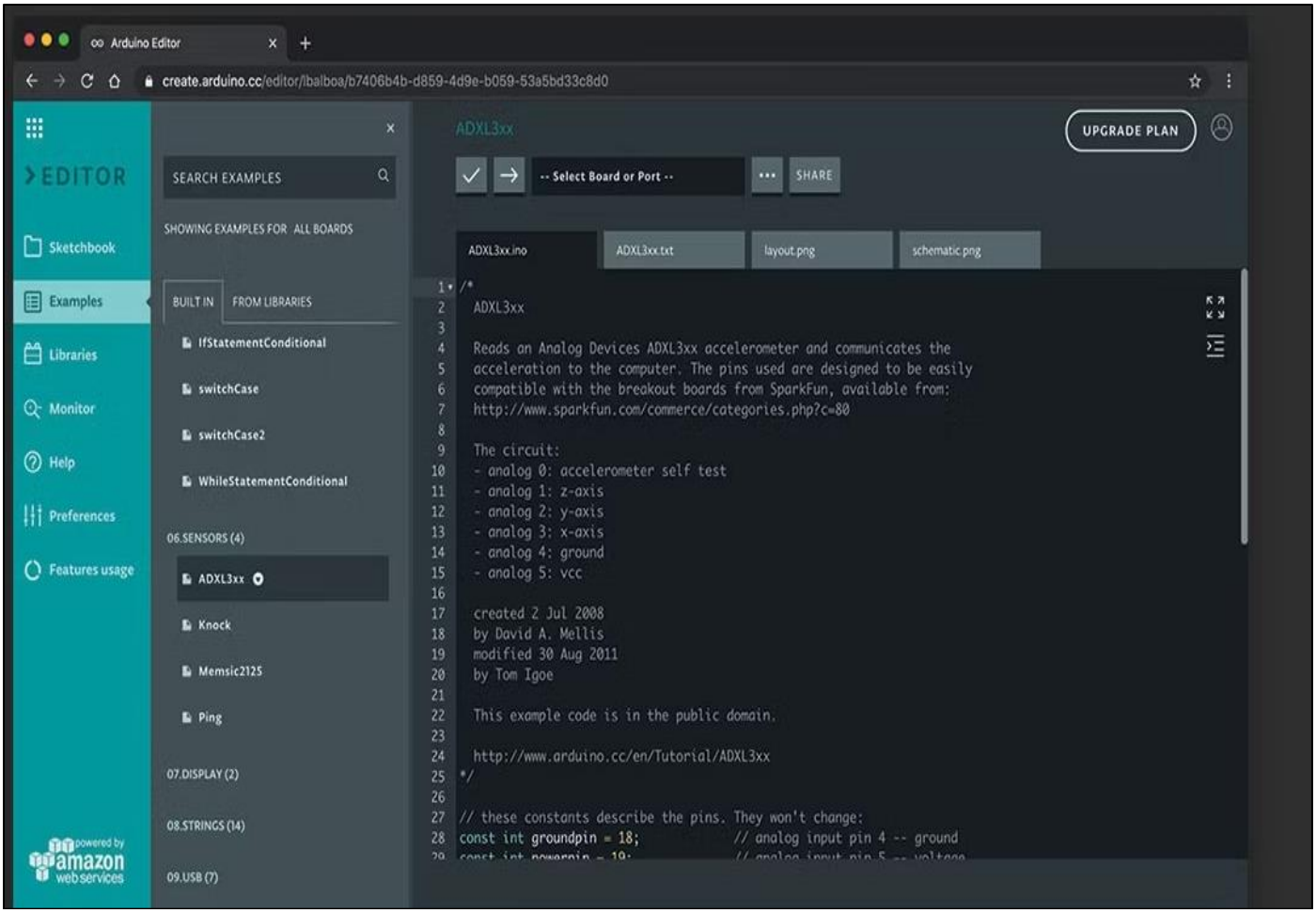

Fig 10 Arduino IDE

- *OpenCV (for Dataset Preparation):*
  Handles face encoding and recognition.

Fig 11 OpenCV (for Dataset Preparation)

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- *AT Commands:*
  Used to interface with the GSM module for sending SMS.

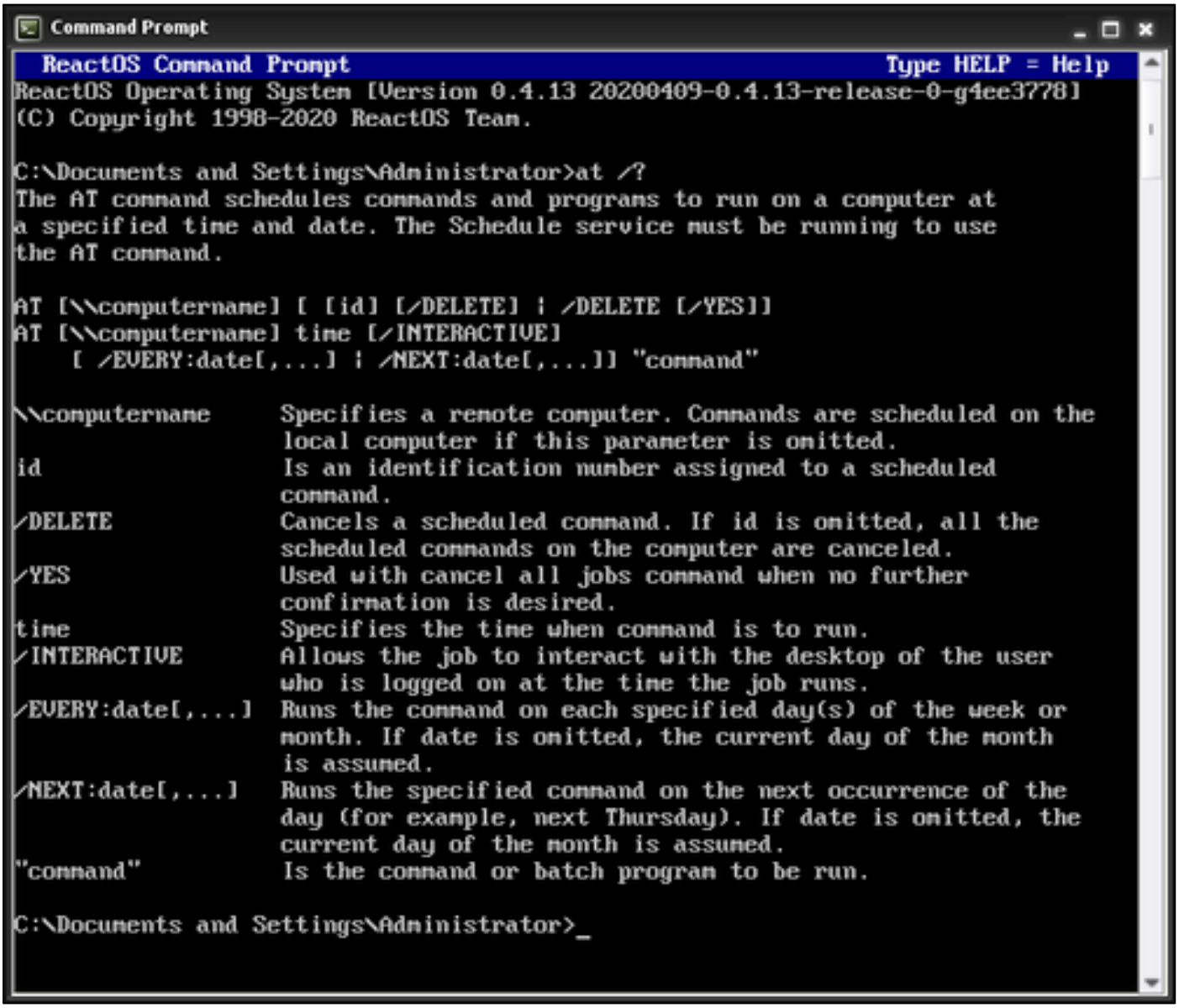

Fig 12 AT Commands

III. METHODOLOGY

➢ *The System Workflow is as Follows:*

- A user presents an RFID card to the RC522 reader.
- The UID is matched with a registered user in the database.
- The system prompts the user to provide a fingerprint.
- Upon successful fingerprint match, the ESP32-CAM captures a facial image.
- The facial image is compared with stored templates using face encoding.
- If all modalities match, the attendance is recorded and timestamped.
- An SMS is sent to the designated phone number.

➢ *The Logic Flow is Divided into Enrollment Process and Attendance Logging:*

- *Enrollment Process:*

Prior to system usage, users must be enrolled with their RFID UID, fingerprint template, and facial encoding. This data is stored in the ESP32 memory or an external SD card.

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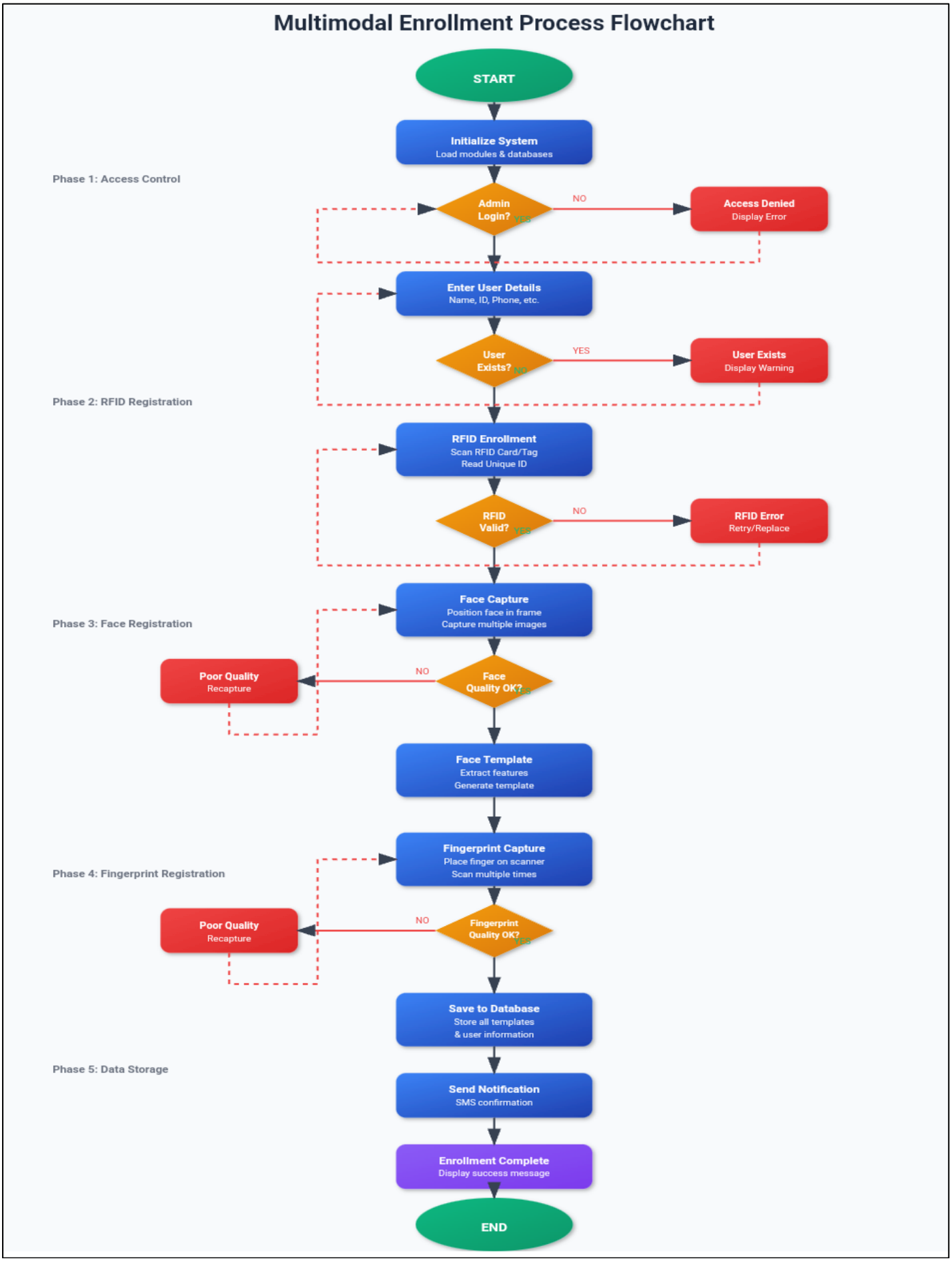

Fig 13 Enrollment Process Flowchart

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- *Attendance Logging:*

Each successful attendance instance logs the user ID, date, time, method of verification, and SMS delivery status. Logs are stored locally and can be exported via serial or SD card.

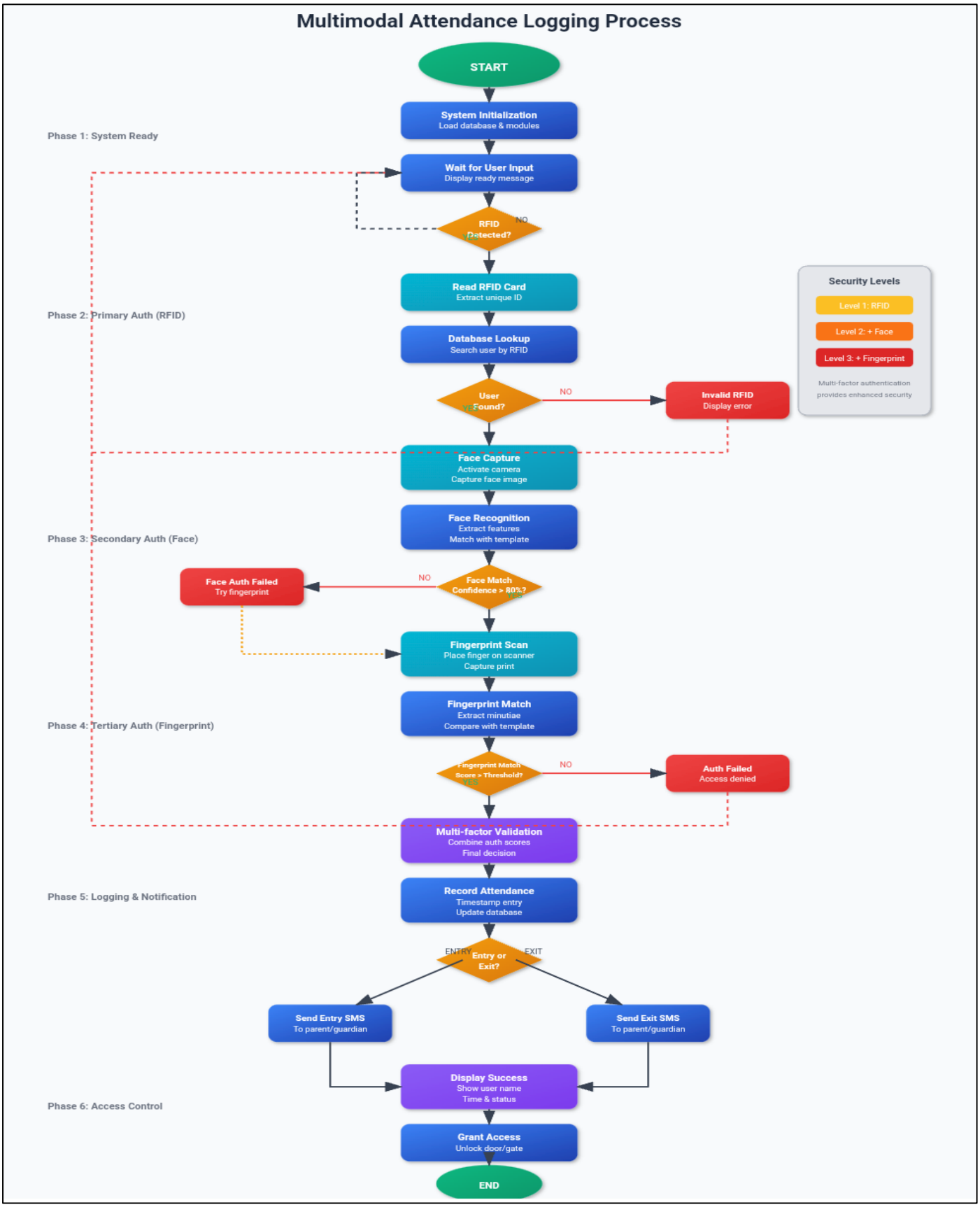

Fig 14 Attendance Logging Process

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IV. RESULTS

➢ *A Total of 30 Persons were Enrolled in the System. Performance Matrices Included:*

- *Authentication Accuracy: 96.7% Overall Accuracy in all the Three Modalities.*

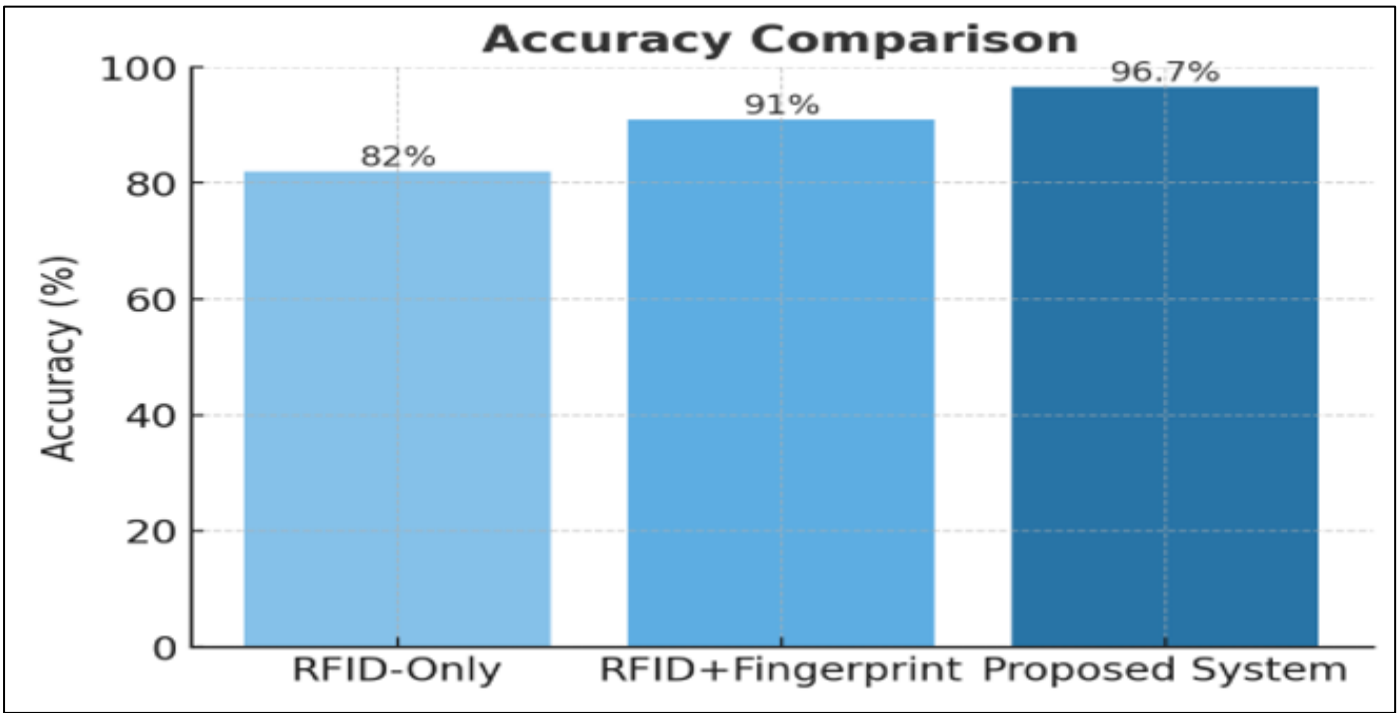

Fig 15 Accuracy Comparison

- Average Verification Time: 5.8 seconds per user.
- Average verification Time: 5.8 seconds per user.
- Average verification Time: 5.3 seconds per user

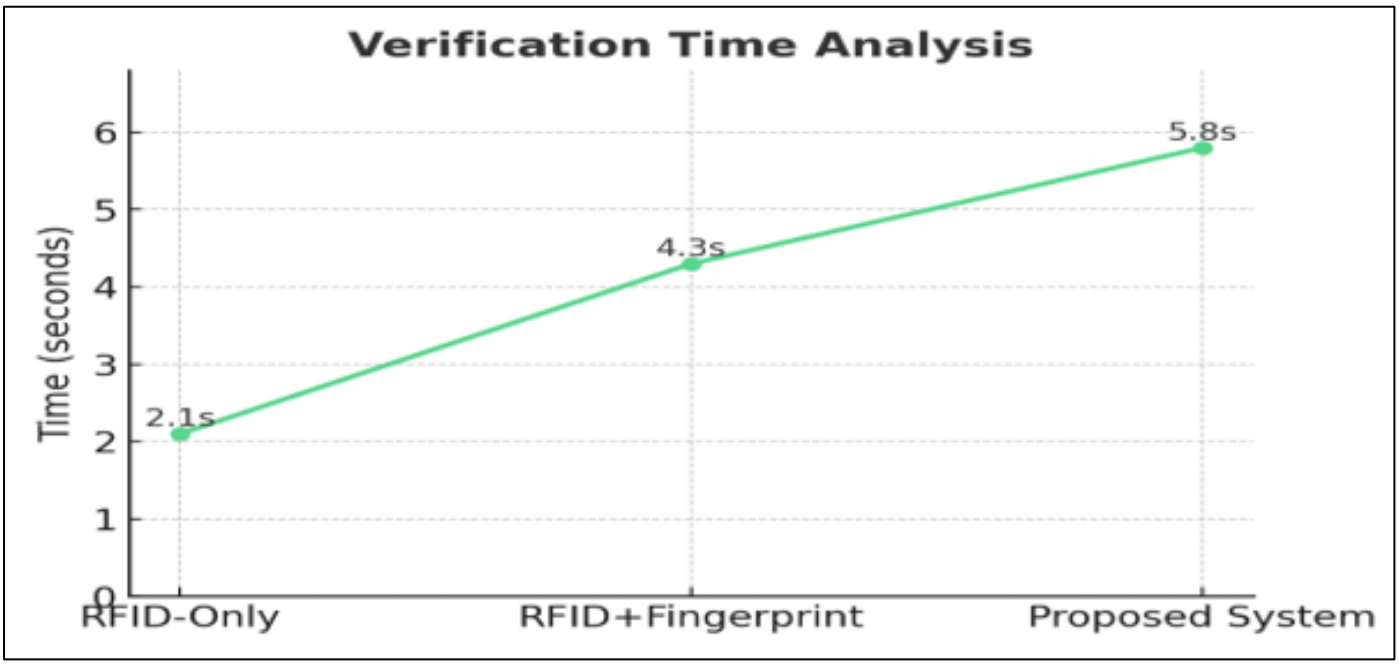

Fig 16 Verification Time Analysis

- False Acceptance Rate (FAR): 0.9%
- False Rejection Rate (FRR): 1.2%

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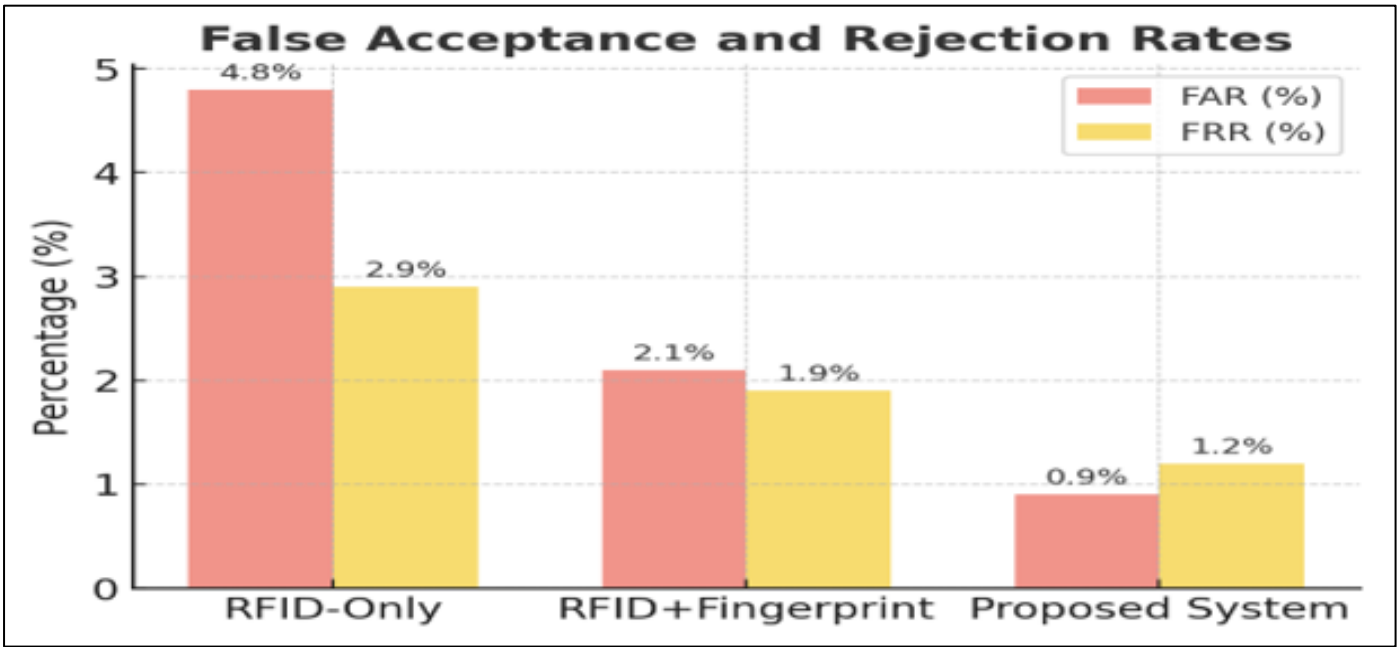

Fig 17 False Acceptance and Rejection Rates

- *SMS Delivery Rate: 100% within 5-15 seconds.*

➢ *Code Overview:*

The system was programmed in C ++ using Arduino idea. Separate features handle RFID scan, verification of fingerprints, face recognition and GSM communication. Non-blocking techniques were used to ensure real-time performance.

```
if(checkRFID()){
  if(verifyFingerprint()){
    if(verifyFace()){
      logAttendance();
      sendSMS();
    }
  }
}
```

➢ *Evaluation:*

Testing showed that combining biometric modalities significantly reduced the chance of impersonation or system bypass. Participants reported that the interface was intuitive, and the SMS feature enhanced transparency.

V. DISCUSSION

The design demonstrates that a multimodal system combining RFID, fingerprint, and face recognition can outperform single-mode systems in terms of security and reliability. The GSM-based alert system introduces real-time accountability. Although lighting variations affect facial recognition slightly, the fallback mechanisms through other modalities ensured reliable performance.

VI. CONCLUSION

This study presents a robust, scalable, and secure multimodal attendance system utilizing RFID, fingerprint, and facial biometrics, enhanced by GSM-based notifications. The system showed high reliability during testing and demonstrated practical value for deployment in institutions requiring secure access and accurate attendance logging. Future improvements will target mobile integration, dashboard analytics, and real-time cloud synchronization.

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